JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIROMENTAL ENGINEERING

ENVIROMENTAL ENGINEERING CHAIR

CHARACTERIZATION AND ENERGY CONTENT ANALYSIS OF MUNICIPAL SOLID WASTE: THE CASE OF AGARO TOWN.

By

Hussen Jemal

A THESIS SUBMITTED TO JIMMA UNIVERSITY, JIMMA INSTITUTE OF TECHNOLOGY, FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING, ENVIRONMENTAL ENGINEERING CHAIR IN PARTIAL FULFILLMENTS FOR THE REQUIREMENTS OF THE DEGREE OF MASTERS OF SCIENCE IN ENVIRONMENTAL ENGINEERING

March, 2018

Jimma, Ethiopia

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SCHOOL OF GRADUATE STUDIES

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As members of the examining board of the final Msc open defense, we certify that we have read and evaluate the thesis done by: Mr. Hussen Jemal entitled: characterization and energy content analysis of municipal solid waste: the case of Agaro Town.

Members of examining board

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the council of graduate studies (CGS) through the department of graduate committee (DGC) of the candidate major department

Declaration

I, **Hussen Jemal**, hereby declare that the thesis work entitled "*Characterization and analysis of energy content of municipal solid waste: the case of Agaro town*" is entirely my original work done for the award of Master of Science (MSc.) degree in Environmental Engineering by the Jimma University, Jimma Institute of Technology. To the best of my knowledge, the work has not been presented for the award of MSc. degree or any other degree either in Jimma University or any other Universities. Thorough acknowledgment has been given where reference has been made to the work of others.

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IV. Approval by Environmental Engineering Chair

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Abstract

Agaro Town is one of the growing towns in the south western part of Ethiopia with poor solid waste management practice. Waste collection and disposal is a challenge for many municipalities in Ethiopia and Agaro town is no exception. The recently increasing municipal waste in the town may be attributed to rapid population growth and urbanization. The collection of solid wastes by the municipality is inappropriate that may lead to various public health problems and environmental impacts. All the wastes generated in the town end up at the Koye dump site without any recovery of valuable material or energy. The study was carried to characterize and analyze energy content of municipal solid waste in Agaro Town administration, South Western Ethiopia. Understanding the energy potential of the waste in the dumpsite is the base for waste utilization for energy sector. Hence, this study was undertaken to evaluate the energy potential of municipal solid waste at Koye dumpsite in Agaro Town. To get reliable data for characterization and generation rate analysis, 100kg solid waste were sampled from Koye dumpsite. The proximate and ultimate analysis of municipal solid waste was determined in Jimma University, College of Agriculture and Veterinary Medicine department of post-harvest Laboratory. From 100kg sample waste collected only 85.57kg of waste used for analysis the other waste which accounts about 14.43kg is metal and glass removed from analysis since it consume high energy during combustion. According to the data analysis the composition of the waste is as follows: chat waste 39.87%, plastic 19.05%, cardboard 12.27%, paper 9.71%, food waste 8.29%, textile 6.01% and yard waste 4.8%. The rate of generation of solid waste in the town is very fast and then it reaches about 7750m^3 per year. The per capita waste generation rate in the Town is 0.58kg/day/ Person. The results of the proximate analysis showed that high volatile matter indicate the wastes can easy burn making it suitable for energy recovery. The calorific value of the waste is about 16490.22kJ/kg this indicates the waste is important source of energy. The analysis also showed that the organic portion of the waste has chemical compositions with and without sulphur are $C_{568.918}H_{1416.449}O_{507.020}N_{10.184}S$ and $C_{55.866}H_{139.098}O_{49.787}N$ respectively. Also the waste had 69.47kg dry mass and about 172.97 kg/m^3 density. The compositional analysis as well as the proximate and ultimate analysis clearly indicates that the municipal solid waste of Agaro Town is suitable for energy recovery.

Key words*:* Characterization, Energy Content, Municipal solid waste, Agaro Town, Ultimate Analysis, Proximate Analysis.

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Tables of contents

List of tables

List of figures

List of plates

Acronyms

AD	Anaerobic digestion
ASTM	American Standard Test Method
EC	Energy content
GHG	Green house glass
GWP	Global warming potential
HCF	High calorific fraction
HHV	High heating value
IWM	Integrated waste management
LFG	Landfill gas
LHV	Low heating value
MBP	Mechanical and biological process
MC	Moisture content
MSW	Municipal solid waste
MSWM	Municipal solid waste Management
PEF	Process engineered fuel
PG	Power generation
PPF	Paper plastic fraction
RDF	Refuse Derived fuel
UN	United Nation
WEEE	Electrical waste electronic equipment
WHO	World health organization
WTE	Waste to Energy

CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1 Background of the study

Humans have been producing solid waste forever as part of life. Mass production of solid waste began when humans abandoned nomadic life and began to live in communities at around 10,000 BC. In ancient cities, solid wastes piled up and people lived among wastes and squalor. Actions were taken only when the social discards became dangerous for defense. The first law that requires all waste material to be deposited more than a mile out of town was passed in Athens around 500 BC as the piles of rubbish provided an opportunity for invaders to scale up. Dump sites were created and efforts were made to transport the wastes farther away the city upon growth of population (Gawaikar and Deshpande, 2006)

Human activities generate waste materials that are often discarded because they are considered useless. However, many of these waste materials can be reused and can become a resource. Solid waste generation within residential, commercial, institutional, industrial, construction and demolition, treatment facilities and agricultural is as a result of human activities. These sources of waste are highly heterogeneous and are made up of important waste streams such as plastics, yard waste, food waste, papers, metals, glass, textiles, leather and other miscellaneous materials (Zurbrugg, 2002; Gawaikar and Deshpande, 2006 and Ejaro and Jiya, 2013).

Solid waste management is as old as human civilization although only considered an engineering discipline one century ago. Solid-waste management may be defined as the practice associated with controlling the generation, storage, collection, transfer and transport, processing and disposal of solid waste in accordance with the best principles of health, economics, engineering, conservation, aesthetics, and environmental considerations.The scope of solid-waste management includes all administrative, financial, legal, planning and engineering functions involved in the solutions to all problems of solid waste.

Waste management being a major environmental and health challenge around the world today is more pronounced in developing countries. The challenge is to minimize how much waste is generated and to convert waste into a resource. Identification of these valuables in the solid waste stream and their quantities has called for the development of important recovery and recycling technologies and designs for treatment to extract the exact economic benefit of these materials (Ejaro and Jiya, 2013).

The organic fraction of MSW is an important component, not only because it constitutes a sizable fraction of the solid waste stream in a developing country but also because of its potentially adverse impact upon public health and environmental quality. A major adverse impact is its attraction of rodents and vector insects for which it provides food and shelter. Impact on environmental quality takes the form of foul odours and unsightliness. In most developing economies, biodegradables are the highest fraction; hence the strategic development of bioconversion processes to reduce the quantities of the generated waste and consequent benefit over mere disposal. Biogas and compost production from such a renewable source offers an advantage because of its continual and sustainable supply provided their production cost are minimized (Pichtel, 2005; Gawaikar and Deshpande, 2006; Ahmad and Jehad, 2012).

Waste characterization is a major factor in the waste management system. It is considered as a basis for the design of efficient, cost effective and environmentally compatible waste equipment. The percentage components in waste to be combusted must be determined on the basis of waste characterization analysis (Beck, 2005; Chang *et al*., 2008; Alhassan and Tanko, 2012).

The characterization of waste has the purpose of providing information for addressing issue such as national policy setting, regional planning of waste management, legal aspects, administration, cost accounting, design and operation of facilities and environmental assessment. The primary purposes for waste characterization are to provide data on waste quantities and composition for use in regional or national waste statistics as a basis for policy setting on recycling, classify waste as hazardous or non-hazardous waste according to national regulation, which will determine the legal framework for the handling of the waste, document specified quality criteria for recycled materials, determine the efficiency of a recycling scheme, determine waste generation rates for the forecasting of waste quantities according to population growth, rehabilitate or retrofit facilities, optimize plant and monitor emission and characterize waste quantity and composition for the design and subsequent management and operation of a disposal system or material or energy recovery facilities (Oumarou *et al*,. 2012).

The waste composition must be known in order to select the most economical collection means, plan for suitable sanitary landfill sites, design and operate an efficient incineration plant, design composting plant or grinding plant, forecast accurately the cost and efficiency of operation when choosing a particular method of disposal and finally forecast future demand (Aguilar-Virgen *et al*., 2010).

This study focused on the characterization and energy content analysis of solid waste in Agaro Town for the purpose of choosing waste as energy source. Among those environmental issues solid waste management is a critical one because as long as humans have been living in settled communities, solid waste generation has been an unavoidable and critical issue both in developed and developing nations. As a result, solid waste management became a worldwide agenda at United Nations conference on environment and development in Rio dejeneiro in 1992 with a great emphasis on reducing wastes and maximizing environmentally sound waste reuse and recycling at first step in waste management (UNEP, 2000).

In developed countries, the daily life of people can generate greater quantity of solid waste than developing countries, but most parts of developed nations are efficient in handling the waste as compared to the developing countries cognizant of their technologically complex, institutionally efficient and cost effective solid waste management systems. On the contrary, developing countries produce less per-capita solid waste. However, they have limited capacity to collect process and dispose the generated waste due to inadequate infrastructure, finance, political instability, inefficient institutional capacity and structure, and low level of awareness, For instance, cited by Solomon (2006) “about 50 to 80 percent of the solid waste produced in urban areas of developing countries as well as poorest parts of the middle-income countries is estimated to be left uncollected”. These situations introduced numerous discomforts to communities and intimidate humans’ health through direct contact and contamination of water and soil. Recently, WTE technologies are gaining momentum as favorable waste management options (Smith, 2010).

There has been increased recovery of recyclable materials from MSW rather than relying on sanitary land filling as the primary long-term method of solid waste disposal. WTE or energy from waste refers to any waste treatment (anaerobic digestion: AD, incineration, pyrolysis, gasification, plasma arc, and refuse derived fuel: RDF) that generates energy in the form of electricity or heat energy from a waste source. All in all, WTE seems a viable option for reducing the waste volume to the lowest as well as producing energy from the waste. WTE technologies can usually reduce the volume of the original waste by 90%, depending on the composition and use of outputs (Rogoff and Screve, 2011).

The waste management hierarchy generally follows waste reduction/minimization, reuse, recycle, energy recovery and disposal. An integrated approach to WTE that practices waste segregation and pre-treatment of waste does not by-pass the waste hierarchy, and hence is the more suitable approach to WTE recovery. The objective of this study was to characterize and analyze energy content of municipal solid waste of Agaro Town administration.

1.2 Statement of the problem

Municipal solid waste (MSW) comprises of combined domestic, commercial and industrial waste generated in a given municipality or locality. The main problem facing policy makers in the waste management sector in the municipality is how to project and therefore fairly predict the amount and the composition of MSW that is likely to be generated in the near future in order to device the most appropriate treatment and disposal strategy. The main problem facing policy makers in the waste management sector in the municipality is how to project and therefore fairly predict the amount and the composition of MSW that is likely to be generated in the near future(50 year) in order to device the most appropriate treatment and disposal strategy (Fobil, 2005 Kothari, *et al.*, 1990).

Solid waste management (SWM) has emerged as one of the greatest challenges facing state and local government environmental protection authorities in Ethiopia. The volume of solid waste being generated continues to increase at a faster rate than the ability of the authorities to improve on the financial and technical resource needed to parallel this growth. Solid waste management in Ethiopia is characterized by inefficient collection methods, insufficient coverage of the collection system and improper disposal of solid waste as such , most cities and towns are characterized by waste disposal dumpsites situated on any available free land road streets, drainages etc (Lem Ethiopia, 2006).

According to Agaro Town municipality, solid waste management is a major problem in the Town. The waste segregation system at the source has not yet been strictly adapted by majorities of people. There is no sanitary landfill site. Collected wastes are dumped in the open dumpsite, which has a potential to cause serious health hazards. Understanding the energy potential of the waste in the dumpsite is the base for waste utilization for energy sector. Hence, this research is undertaken to evaluate the energy potential of municipal solid waste at Koye dumpsite in Agaro Town administration.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the study is to characterize and analyze energy content of municipal solid waste of Agaro Town administration.

1.3.1The specific objectives of this study

1. To find the chemical composition of the organic fraction of municipal solid waste of Agaro town.
2. To identify the component of municipal solid waste of the town.
3. To determine the moisture content, dry mass and density of municipal solid waste of the town.
4. To determine the energy content/heat value of solid waste of the town.

1.4 Research questions

1. What is the chemical composition of the organic fraction of municipal solid waste of Agaro Town?
2. What is the component of municipal solid waste of Agaro Town?
3. How much moisture content, dry mass and density does municipal solid waste of Agaro Town have?
4. What is the energy content/heat value of solid waste of Agaro Town?

1.5 Significance of the study

Waste characterizations are essential data for waste disposal facilities planning and waste management policy formulation. The characterization of municipal solid waste is important in designing waste management and waste to energy system. The cost of waste management will be minimized, when the dumped municipal solid waste is utilized as a source of energy. In addition, this will reduce environmental pollution and land requirement for disposal. The municipal assemblies manage solid waste with the aim of providing good quality sanitation services in order to keep the cities clean and to enhance public health and safety. The amount of waste that produced in Agaro Town is increasing so in order to overcome the problem the waste must be managed properly. Agaro Town Authorities especially municipalities may use the results of this study for waste disposal facilities planning and waste management policy formulation. The Ethiopian mine and energy Authorities may use the result of this study for energy production.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to solid waste

Solid waste is material, which is not in liquid form, and has no value to the persons who are responsible for it (Zurbrugg, 2003),from the days of primitive society, humans and animals have used the resources of the Earth to support life and to dispose of waste .In early times, the disposal of human and other waste did not pose a significant problem, for the population was small and the amount of land available for the assimilation of waste was large. Problems with the disposal of waste can be traced from the time when humans first began to congregate in tribes, villages, and communities and the accumulation of waste become a consequence of life (Techobanaglous *et al.*, 1993).

A material is discarded if it is abandoned by being disposed of; burned or incinerated, including being burned as a fuel for the purpose of recovering usable energy; or accumulated, stored or physically, chemically or biologically treated (other than burned or incinerated) instead of or before being disposed of a material is discharged, deposited, injected, dumped, spilled, leaked or placed into or on any land or water so that such material or any constituent thereof may enter the environment or be emitted into the air or discharged into groundwater or surface water. To a large extent ecological phenomena such as water and air pollution have also been attributed to improper management of solid waste (Techobanaglous *et al.*, 1993).

The booming growth of cities of the developing world has outpaced the financial and manpower resources of municipalities to deal with provision and management of services, of which solid waste is the major one. Lack of these services greatly affects the urban poor, women and children who are vulnerable to health hazards (Birke, 1999). Improper management of solid waste has direct adverse effects on health. About 22 human diseases are related to improper solid waste management (World Bank, 1999).

2.2 Municipal solid waste

The term municipal solid waste (MSW) is normally assumed to include all of the waste generated in a community, with the exception of waste generated by municipal services, treatment plants, and industrial and agricultural processes (Tchnobanoglous and Kreith, 2002). MSW includes various wastes generated from people's daily and industrial process. With the improvement of people's life, the increasing amount of MSW is becoming a problem baffling every government. Without effective handling, MSW may seriously threaten people's health, improvement of environmental and man's sustainable development. MSW consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint and batteries (UN, 1999).

There are several technologies for converting MSW to energy. Moreover Solid Recovered Fuel (Refuse Derived Fuel - RDF) offers significant environmental and market opportunities, is relatively clean and can be traded in the market for numerous energy applications replacing fossil fuels. Derived fuel such as recovered fuel (REF), packaging derived fuel (PDF), paper and plastic fraction (PPF) and process engineered fuel (PEF) (UNEP, 2005; Gendebien *et al.*, 2003). With certain value as a resource, incineration for energy recovery (Sheng, 1994) and low-temperature pyrolysis (Zhang, 1995) are considered effective measures preventing pollution. Incineration for energy recovery has been widely adopted in advanced countries (Zhang, 1997) and investigated with great effort in domestic scientific institutes (Jiang, 1998; sheng, 1997; Yang, 1998; Nie, 1999). The MSW industry has four components: recycling, composting, land filling and waste to energy (WTE) via incineration (Tchobanoglous *et al.*, 1993).

According to ASTM standard (2003) that RDF is a shredded fuel derived from MSW which metal, glass and other inorganic materials have been removed and has particle size 95 weight % passes through a 2-in square mesh screen. MSW composition is varied from different sources, seasons and living behaviors. Raw MSW has high moisture content, low calorific value, wide range of particle size distribution and high ash content. These reasons make using raw MSW as fuel is difficult and unattractive. RDF presents several advantages as a fuel over raw MSW. The main advantages are higher calorific value which also remains fairly constant, more uniformity of physical and chemical composition, ease of storage, handling and transportation, lower pollutant emissions and reduction of excess air requirement during combustion (Caputo and Pelagagge, 2002).

According to Agaro Town administration cleansing agency "municipal solid waste" includes commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes. In simple words the municipal solid waste can be defined as the waste that is controlled and collected by local authority and municipality.

2.3 Classification of Municipal Solid Waste

MSW is defined as unwanted material and/or substances generated in a city or municipal area and the components of which generally include food/organic waste, infectious waste, hazardous waste, electrical waste electronic equipment(WEEE) and packaging waste (Tanaka, 2010).

Fast rising population level, explosion of economic growth, rapid urbanization and the ascend in community living standards are the detrimental factors responsible for the accelerated rate of municipal solid waste (MSW) generation in developing countries . Solid waste management (SWM) appears to be a worldwide growing challenge in urban areas, especially in the rapidly rising towns and cities of the developing countries. SWM reflects a foremost environmental and economic issue almost in all countries. But municipal solid waste management (MSWM) is an extremely ignored spot mostly in urban cities of developing countries. Due to progressive urbanization, the management of SW is appearing as a major threat to environment and public health in urban zones.

Three primary sources of MSW are classified as residential area, institutional and commercial waste (Tariq *et al.,* 2007). The two main factors that effect on type and quantity of waste are culture and society consumption pattern. Generally MSW consist of around twenty different categories: food waste, paper (mixed), cardboard, plastic (rigid, film and foam), textile, wood waste, metals (ferrous or Non-ferrous), diapers, news print, high grade and fine paper, fruit waste, green waste, batteries, construction waste and glass, these categories can be grouped into organic and inorganic (Marine, 2007).

2.4 Sources and types of Municipal Solid Waste

Numerous classification criteria have been utilized in order to categorize municipal solid waste constitutes. Some of those criteria are sources from which solid wastes emanate and nature of solid waste components. On the basis of the nature of items that constitute solid wastes, it can be classified into organic or inorganic, combustible or non-combustible and putrescible or non-putrescible (G/Tsadkan, 2002). Types of solid waste classification may be based on origin (e.g., food waste, rubbish, ashes and residues, demolition and construction, agriculture waste), characteristics (biodegradable and non-biodegradable) and risk potential (hazardous nonhazardous waste) (Puopiel, 2010).

Fundamental understanding of the sources and types of solid wastes is key in evaluating the composition and generation rates of MSW sources in a community. The knowledge of the sources and types of waste in an area is required in order to design and operate appropriate solid waste management facilities (Oyelola and Babatunde, 2008).

Normally, MSW can be classified by the source of origin of waste from where the municipalities or other local authorities collect the waste, such as residences, house hold, schools, hospitals, offices, shops, markets (the definition of the source of typical waste is shown in table 2.1)

2.5 Characteristics of Municipal Solid Waste

The characteristics and quantity of the solid waste generated in a region is not only a function of the living standard and lifestyle of the region's inhabitants, but also of the abundance and type of the region's natural resources (Anon, 2005). To ensure the amount of waste that ends up at the final disposal site is minimum. The most sustainable waste management strategy, it is first necessary to identify the nature and composition of the city's urban waste (Gomez *et al*., 2009). Waste characterizations are essential data for waste disposal facilities planning and waste management policy formulation. The characterization of municipal solid waste is important in designing waste management and waste to energy system.

Table 2.1: Source and types of MSW (UNEP, 2013)

Source	**Definition**	**Types of waste**
Residential area	Single family and multifamily detached dwellings low-medium and high-rise apartments, etc	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, tin cans, aluminum, other metal, ashes, street leaves, special wastes (including bulky items, consumer electronics, white goods, yard wastes collected separately, batteries, oil, and tires) and household hazardous wastes
Commercial area	Waste is from the places of trade, transportation or service: offices, markets, stores, grocery shops, restaurants, hotels	Food waste, glass, paper, cardboard, plastics, metal, bulky waste, electronics, batteries, hazardous waste, construction and domestic waste.
Institutional area	Waste is from school, government centers, hospitals, police station, post offices	Paper, cardboard, plastics, wood, food waste, glass, metals, bulky waste, electronics, batteries, hazardous waste.
Recreational area	Waste is from the recreational places, tourist attraction or municipal service area: dam lake, beach, reservoir, temples, archaeological site	Food waste, packaging, street refuse, paper, cardboard, tree trimmings, dead animals.

2.6 Municipal solid waste characterizations

Physical characterizations are significant for evaluating disposal design, material recovery and energy recovery from MSW. Physical and chemical properties of MSW are used to describe the individual components in waste stream, usually based on percentage by weight. For example, 100kg of MSW consists of 68% of organic waste. Such physical and chemical property of MSW is important to assess what type of appropriate disposal method is to be carried out (Dev, 2007).

2.7 Methods of municipal solid waste characterization

Physical and chemical analysis of the waste is important to characterize and classify the municipal solid waste for its proper management and for accurate estimation of the amount of landfill gas produced from the municipal solid waste. Physical and chemical characteristics indicate the composition of the MSW. They are directly influenced by the local aspects such as food habits, culture, socio-economic, seasonal, and climatic conditions (Bhoyar *et al.*, 1996). Four methods for estimating waste quantities and composition can be identified: direct sampling (also referred to as waste stream analysis and waste audits), material flow, surveying waste generators, and literature sources (Gerald, 1997).

Direct sampling: Direct sampling involves sampling, sorting, and weighing materials from the waste stream of a specific generator. This method has been used to estimate the composition of municipal waste streams. Representative sampling methods must be employed to achieve accurate results. When using the direct sampling method, the following questions must be addressed: How will representative samples of waste be obtained; and how many samples should be selected to achieve the desired level of accuracy in the results? The responses to these questions will influence the cost of conducting the study as well as the usefulness of the data.

Waste stream analysis: Waste stream analysis is another term used for characterizing the waste stream of a specific operation for a designated time period. Waste stream analysis is defined as a method for collecting, sorting, and measuring the amount and type of waste generated by an operation. Results of a waste stream analysis provide data about the amount and type of waste/residues in the waste stream. Data should be collected for a minimum of one week; the length of time depends on how the data are to be used and the accuracy required. The results are averaged to estimate the amount of waste that the facility generates for a period of time.

Waste audit: the basic objectives of a waste audit are similar to a waste stream analysis. A waste audit involves a more detailed assessment of waste. The waste audit assesses not only the output (waste), but also the input, such as food products, packaging materials, office supplies, mail, or any process that results in materials that must be discarded. The detailed and complicated analysis of material flow through an institution will enable the facility to find the amount purchased, used, recycled, and disposed of for different materials. A waste audit can involve all materials or focus on a specific material, such as cardboard or office paper that is generated by a facility or department.

Material flow: the material flow method applies the concept of conservation of mass to track quantities of materials as they move through a defined system or region. The material flow methodology in this instance is based on the production weight data for materials and products. Generation data are the result of making specific adjustments for imports, exports, and diversions to the production data by each material and product category. The method also considers the useful life of products. One of the problems with the material flow approach is that it is difficult to quantify product residues, such as food left in the container and detergent remaining in the package.

Surveying waste: surveying industrial generators, such as food processors can provide useful data in quantifying waste generation. More accurate data can be obtained if the waste/residues are measured at the disposal site.

Literature sources: Data on waste/residues quantities and composition are available from a variety of sources including public agency documents, engineering reports, trade publications, and professional journals. These data may be helpful in assisting managers in identifying the type of residues/waste generated by a specific industry or activity. However, caution should be exercised when operational decisions are made based on data from the secondary sources. Waste characterization and generation rate studies are recommended for operational uses rather than relying on published data since each study site is unique.

2.8 Solid waste management

Humans and animals have used the resources of the Earth to support life and to dispose of waste. In early times, the disposal of human and other waste did not pose a significant problem, since the population was small and the amount of land available for the assimilation of waste was large, problem with the disposal of waste can be traced from the time when humans first began to gather together in tribes, villages and communities and the accumulation of waste become a consequence of life (Tchobanoglous *et al*, 1993). The management of solid waste is one of the challenges facing any urban area in the world. An aggregation of human settlements has the potential to produce a large amount of solid waste; the collection, transfer and disposal of that waste has been generally assumed by municipal governments in the developed world. The format varies, however in most urban areas, Garbage is collected either by a government agency or private contractor, and this constitutes a basic and expected government function in the developed world.

Municipal solid waste (MSW) management has become a major issue of concern for many under-developed nations; especially as populations increase. The problem is compounded as many nations continue to urbanize rapidly; 30-50% of populations in many developing countries is urban (Thomas-Hope 1998) and in many African countries the growth rate of urban areas exceeds 4% (Senkoro, 2003).

Urbanization is not necessarily a new phenomenon on the continent of Africa, as shown by urban centers like Addis Ababa and Cairo (Onibokun and Kumuyi, 2003). What is noteworthy about contemporary urbanization in Africa is its fast pace. Although Africa is presently among the least-urbanized regions of the world, it is recording the highest rates of urbanization. For example, Africa and Asia recorded urban growth of 4.9% and 4.2%, respectively, between 1990 and 1992. However, urban growth in Europe and North America in this period was only 0.7% and 1.0%, respectively (UN, 1995).

Although developing nations do spend between 20 and 40% of municipal revenues on waste management (Schübeler, 1996; Thomas-Hope, 1998; Bartone, 2000), this is often unable to keep pace with the scope of the problem. In fact, when the governments of African countries were asked by the World Health Organization to prioritize their environmental health concerns, the results revealed that while solid waste was identified as the second most important problem (after water quality), less than 30% of urban populations have access to "proper and regular garbage removal" (Senkoro, 2003).

2.9 Components of municipal solid waste management

Solid waste management includes the process of generation, collection, storage, transport and disposal or reuse and re-circulation or incineration or any relevant method of disposal (WHO, 1971). These are done in accordance with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations. In its scope, it includes all administrative, financial, legal, planning and engineering functions involved in the whole spectrum of solutions to problems of solid wastes thrust upon the community by its inhabitants (Tchobanaglous, *et al, 1997).* Municipal Solid Waste Management system affects the utilization of municipal solid waste for energy sources.

2.9.1 Waste Handling, Sorting, Storage, and Processing at the source

Waste handling and sorting involves activities associated with management of wastes until they are placed in storage containers for collection. Handling also encompasses the movement of loaded containers to the point of collection. Sorting is an important component of waste management and best-done onsite. However, there are various stages of sorting. These can be identified as the following: At the source or house hold level, at the community bin (municipal bin), at transfer station or centralized sorting facility, at waste processing site (pre-sorting and post sorting) and at the landfill site. Sorting Operations can be carried out in three ways: Manual sorting, Semi-mechanized sorting, and fully mechanized sorting (Birke, 1999).

The size of premises, nature (type) and generation rate of solid waste determines the type of storage to be used. Storage facilities must be animal and insect proof washable and robust enough to meet the exigencies in normal use. There is a limit to the duration that solid waste can be stored at source (in the premises) based on the type and source of solid waste. Solid waste should be collected and disposed of from temporary stores to final disposal site before breeding various disease-carrying vectors. Uncovered containers of waste are exposed to human and animal scavengers that litter waste around and create community health problems. Onsite storage is of primary importance because of public health concerns. Open ground storage, make shift containers should always be avoided and only closed containers should be used. Processing at the source involves backyard composting. Storage of wastes can be done at three levels: At source, at community level and at transfer stations (WHO, 1971).

According to Agaro Town cleansing management agency waste handling is done by push cart containers to the point of collection. Solid waste is stored under plastic bags at the point of generation in residential area before it will be transported to the escape point. In the commercial and institutional areas, it will be stored in a 2.1 m^3 standard container. Minor solid wastes along streets are temporarily stored in a dust bin. Sorting of waste takes place at various levels in the waste management process. The first level of source separation is at household: plastic materials, glass, bottles, are considered as valuable and usually sorted out for reuse. In the second level several collectors represent the second stage: Street boys, private sector enterprises, scavengers at municipal dumpsite, and the korales. Except these collectors almost all waste streams are not segregated from the source. the assessment made

Show that wastes are not properly segregated and stored as normally in the Town of Agaro. Municipal Solid Waste is commonly stored in rectangular concrete open bin. Sorting of waste at the source play a great role to utilize based on their characteristics for energy evaluation and also have an advantage to stop extra cost for sorting.

2.9.2 Collection and transportation/transfer

Collection is the component of waste management which comprises lifting and removal / Passage of a waste material from the source of production to either the point of treatment or final disposal. Collection of generated solid waste is the crucial part in MSW management. Efficiency in collecting solid waste & segregating it decides how well solid waste is managed and recovered for energy. Collection includes not only the gathering of solid waste, but also the transport of these materials, after collection, to the location where the collection vehicle is emptied. This location may be a material processing facility, a transfer station or a landfill disposal site. Now a days it is one of the most important issues in municipal administration, particularly in metro cities. Huge generation of MSW is one of the reasons behind the administrative Difficulty. The collection of municipal solid waste is a public service that has important impacts on public health and the appearance of towns and Cities (Tchobanolous, *et al* 1993).

Common Collection Types of municipal solid waste are Community bins, Door-to-Door collection, Block collection and Curb side collection (Tchobanolous *et al.*, 1993). .The waste collection methods that are mainly adopted in Agaro town are Door to door collection by small and micro scale solid waste collecting enterprises. Here the worker uses a pushcart for the collection of waste without separating at the source and transfer station. In concept this activity includes collection of wastes by generators up to the temporary storage sites in their compound (Senkoro, 2003).

Transfer and transport involves two steps: The transfer of wastes from smaller collection vehicle to larger transport vehicle and, the subsequent transport of the wastes usually over long distances, to a processing or disposal site. The transfer usually takes place at a transfer station. The most common method for transfer is manual transfer from community bin to trucks. The transfer of waste directly from pushcarts to trucks by meeting at a specified time and place called synchronization is suggested by which a suitable option for the door to door collection method. Whereas solid waste collection and transportation from organization, higher commercial institution, embassies, health care institution and large scale industries are conducted by private solid waste collection companies (Karadimas, 2004).

2.9.3 Processing and transformation of Solid Waste

This functional unit encompasses the recovery of the sorted materials, processing of solid waste And transformation of solid waste that occurs primarily in locations away from the source of Waste generation. Sorting of the mixed waste usually occurs at a material recovery facility, transfer stations, combustion facilities and disposal sites. Waste processing and transformation solid waste processing reduces the amount of material requiring disposal and, in some cases produces a useful product. Examples of solid waste processing technologies include material recovery facilities, where recyclable materials are removed and/or sorted; composting facilities where organics in solid waste undergo controlled decomposition; and waste-to-energy facilities where waste becomes energy for electricity (Techobanaglous *et al.*, 1993).

Land filling continues to be required even if solid waste processing technologies are employed because all of these technologies produce some sort of residue or handle only a portion of the waste stream. For example, land filling is still required for ash and bypass

Waste (waste that can't be burned) from waste-to energy facilities. Thus, solid waste processing technologies do not replace land filling; rather they are a part of an integrated system that reduces the amount of material that requires landfill disposal (Zurbrugg, 2002).

The different types of processing techniques are reuse/recycling and composting. Recycling materials waste) into new products to prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy incineration) and water pollution (from land filling) by reducing the need for "conventional" waste disposal, and lower greenhouse gas Reduce, Reuse, and Recycle" waste hierarchy. is a process to change (usage, reduce air pollution (from emissions as compared to plastic production. Recycling is a key component of modern waste reduction and is the third component of the "waste hierarchy) (Techobanaglous *et al.*, 1993).

Composting is a biological process of decomposition carried out under controlled conditions of ventilation, temperature, moisture and organisms in the waste themselves that convert waste into humus-like material by acting on the organic portion of the solid waste (Sathishkumar *et al* 2002). It produces a sludge, which is high in nutrients and can be used as a fertilizer. This is one element of an integrated solid waste management strategy that can be applied to mixed municipal solid waste (MSW) or to separately collected leaves, yard waste or food waste. In Agaro Town cleansing management agency sorting, processing and transformation of solid waste is not worked except informal worker that collect for recycling like plastic and metal wastes.

2.9.4 Thermal treatment combustion/incineration

To reduce waste volume, local governments or private operators implement a controlled burning process called combustion or incineration. In addition to reducing volume, combustors, when properly equipped, can convert water into steam to fuel heating systems or generate electricity. Incineration facilities can also remove materials for recycling. A variety of pollution control technologies significantly reduce the gases emitted into the air, including: Scrubbers-devices that use a liquid spray to neutralize acid gases and Filters-remove tiny ash particles.

Burning waste at extremely high temperatures also destroys chemical compounds and disease causing bacteria. Regular testing ensures that residual ash is non-hazardous before being land filled (Zurbrugg, 2002). For centuries, burning has been a popular method of reducing the volume of solid waste. The burning of waste was rampant and uncontrolled. While uncontrolled burning of solid waste can be detrimental to health and the environment, confined and controlled burning, known as combustion, can not only decrease the volume of solid waste destined for landfills, but can also recover energy from the waste-burning process. (Zurbrugg, 2002).

Municipal solid waste (MSW) incineration is performed in large scale plants where the fumes and rest products such as bottom ash are handled in order to minimize the effect on the environment. In an incineration plant the combustible fraction of the MSW are oxidized so that energy can be recovered. The chemical reaction in combustion is occurring according to (Eq. 1) (Vallero, 2008).

$(CH)_X + O_2$ ----------- $CO_2 + H_2O$--- (1)

Incineration of municipal solid waste in designed incineration plants with treatment of flue gases and waste water is a system chosen more and more often both in developing and developed countries. Incineration is often a profitable system even though the installation cost is high since production of heat, steam and electricity often leads to a large economic gain. An incineration plant in general consists of pre-treatment of waste, combustion, system for flue gas purification, water treatment and management of slag and ash. Pre-treatment is not always necessary, it depends on the type of incinerator since different types are more or less sensitive to the heterogeneity of the waste. Ash and slag are usually land filled (Sundqvist, 2005).

One important parameter influencing the energy potential in MSW is the heating value. The heating value is a measure of the energy which the waste contains and is determined by the chemical composition of the different fractions (Dong et al., 2003). The heating value regulates the combustion efficiency of the incinerator. It is therefore important to make sure the heating value is high enough so that no additional fuel is needed to fully combust the waste material. The lower heating value (LHV) is defined as the amount of heat produced when combusting a certain amount of fuel assuming all water is in the form of steam and is not condensed (Finet, 1987). The heating value is of great importance for the efficiency and management of the incineration plant. The minimum LHV required for the waste to combust without the addition of other fuel is 7000 kJ/kg MSW or 1.94 MWh/ton (Mauritius, 2007).

One of the advantages of incineration is that the waste residue is minimized; the waste is reduced to approximately 10 % of the volume and 25 % of the weight before combustion (Combes, 2008). The ash is sterilized by the high temperature in the furnace and the ash can be used as filling material if the content of metals and other toxic substances and metals is not too high. Another advantage of incineration is the possibility to sort and reuse metals. This saves both resourses and reduces emissions to the surrounding environment. The metal sorting is easier to perform prior to incineration than before landfilling by using a magnetic or electromagnetic separator (Meri, 2009). The incentive to sort metals is higher when incinerating MSW than in landfilling due to the fact that separation of inert material raises the energy output because of a higher LHV and a reduced risk of breakage. In both systems there is a motive in the gain in the market of reused metal. There is also an incentive for diverting concrete, drywall and glass from the waste stream prior to combustion since the presence of inert matter lowers the heating value, but also due to the limited recycling market for these products (Finet, 1987).

The negative aspect of incineration is the air pollution and waste water problems. Emissions from combustion of waste depend on the substances in the waste and on the technology used; temperature and equipment for flue gas and water treatment. In incineration waste is combusted in a couple of seconds while waste deposited in a landfill takes decades to degrade. The fact that there is an inert residue, leads to a need of a landfill even in the incineration scenario. If there are metals in the ash and slag, toxic leakage from the landfill can lead to contamination of the surrounding environment. Incineration of waste produces a lot of energy. If there is a need for electricity and/or heat, the cost of building an incineration facility often has a short payback time. On the other hand, the cost of investment and operation is high.

However, incineration is only permissible after recyclables (such as secondary raw materials and biodegradable fractions) are separated from the MSW stream. Thus, it is important to consider various options, alternatives, or scenarios of MSW management options with respect to impact on the environment and energy systems. MBT consists of mechanical and biological processes and their combination depending on characteristic of waste. The mechanical stage includes separation of fractions for recycling, light fraction (high caloric fraction, HCF), and contaminants. The rest (low caloric fraction) is fed to the biological process. The resulting HCF, which mostly consists of paper, textiles, plastic, and wood, can be used as an additional energy source in either a cement kiln, power plants or in a waste incineration plant. Incineration provides the best way to eliminate methane gas emissions from waste management processes. Furthermore, energy from waste projects provides a substitute for fossil fuel combustion. These are two ways incineration helps reduce greenhouse gas emissions.

2.9.5 Solid waste disposal

Despite the effectiveness of source reduction, recycling, and combustion, there will always be waste that cannot be diverted from landfills. The safe and reliable long-term disposal of solid waste residue is an important component of integrated waste management (IWM). Solid waste residues are waste components that are not recycled, that remain after processing at a material recovery facility, or that remain after the recovery of conversion products and/or energy (Techobanaglous *et al.*, 1993).

In many developed countries, burial in controlled landfills continues to be the most prevalent means of disposing of solid waste including hazardous waste. About 70% of the urban solid waste is disposed off in this way in the US and most European countries. On the other hand most of the municipal solid waste (MSW) in developing countries is dumped on land in a more or less uncontrolled manner. These dumps make very uneconomical use of the available space, allow free access to waste pickers, animals and flies and often produce unpleasant and hazardous smoke from slow burning fries (Zurbrugg, 2002).

Landfill gas is produced in landfill sites due to the anaerobic degradation of biodegradable organic waste. The gas produced is typically about 60% of methane and 40% CO_2. Landfill gas, with high content of methane, is potentially explosive and, as such, needs to be controlled. In some means of controlling (extracting) the gas is not used, the gas can migrate off site, causing problem to the surrounding environment (Gerald, 1997). Non-engineered disposal is the most common method of disposal in low-income countries, which have no control, or with only slight or moderate controls. They tend to remain for longer time and environmental degradation could be high, include mosquito, rodent and water pollution, and degradation of the land.

Open dumps is the cheapest and the oldest easy method of MSW disposal is 'open dumping' where the Waste is dumped in low - lying areas on the city outskirts and levelled by bull - dozers from time to time. Open dumping is not a scientific way of waste disposal. Open dumps refer an uncovered site used for disposal of waste without environmental controls. The waste is untreated, uncovered, and not segregated. A WHO Expert Committee (1967) condemned dumping as “a most unsanitary method that creates public health hazards, a nuisance, and severe pollution of the environment. Dumping should be outlawed and replaced by sound procedures”.

Sanitary landfills are an alternative to landfills or modern landfill which solves the problem of leaching to some extent is a sanitary landfill which is more hygienic and built in a methodical manner. Disposal of waste in landfills is the most common way to handle MSW trough out the world (Williams, 2007). A landfill is an engineered site where waste is being deposited. The aim of constructing a landfill is for disposal of waste, not to utilize the energy potential in MSW. The possibility to collect landfill gas for energy purposes is only a positive opportunity since it generates energy and lowers the environmental impact of the landfill. Usually, less than 50 % of the produced gas is captured in the collection system (Williams, 2007).

In Agaro Town currently, there is one open dumpsite where a collected waste is disposed off. The site is getting full, surrounded by residential housing areas and public institutions and there is no daily soil cover. The site is becoming detrimental to the surrounding environment. The city government acknowledges the dangers to the environment and the public health derived from the uncontrolled waste dumping. Safe disposal of solid waste is important for safeguarding the public health, environment and wildlife as well. An efficient waste management system is the one that provides ecologically sound disposal option for waste that cannot be reduced, recycled, composted, combusted or processed further (Ali *etal*., 1999). In the site 5000 meter cube solid waste disposed per day. Currently by the coordinator of horn of Africa regional environmental centre and network (HOA-REC/N) 19 hectares of koshe dumpsite covered by soil to collect methane gas for the purpose of LFG-flaring system to get CDM benefit.

2.10 Municipal solid waste Properties

2.10.1 Physical properties

Physical properties are significant for evaluating disposal design, material recovery and energy recovery from MSW. Important physical properties of MSW include specific weight (density), moisture content, particle size and distribution and waste composition.

2.10.1.1 Specific Weight (Density)

Specific weight is defined as the weight of a material per unit volume (e.g. kg/m3, lb/ft3). Usually it refers to uncompacted waste. Density varies because of the large variety of waste constituents, the degree of compaction, the state of decomposition, and in landfills because of the amount of daily cover and the total depth of waste. Density is important because it is needed to assess the total mass and volume of waste, which must be managed. Density varies not only because of the type of treatment it gets (collection and compaction) but also because of geographic location, season of the year, and length of time in storage. Some typical density values of waste components are presented in Table 2.2.

Table 2.2: Typical Specific Weight Values (Techobanaglous *et.al.*, 1993)

Component	**Specific Weight (density), kg/m^3**	
	Range	**Typical**
Food wastes	130 – 480	290
Paper	40 – 130	89
Plastics	40 – 130	64
Yard waste	65 – 225	100
Glass	160 – 480	194
Tin cans	50 – 160	89
Aluminium	65 – 240	160

2.10.1.2 Moisture Content

The most commonly used method of expressing moisture content is as a percentage of the wet Weight of material. Moisture content is important in regards to density, compaction, the role moisture plays in decomposition processes, the flushing of inorganic components, and the use of MSW in incinerators. Moisture increases the weight of the solid wastes and therefore the cost of collection and transport increases. Consequently waste should be insulated from rain or other extraneous water source. Also Moisture content is critical determinant in the economic feasibility of waste treatment by incineration. During incineration energy must be supplied for evaporation of water and raising the temperature of vapour (Williams, 2007). Some typical moisture contents are shown in Table 2.3. The wet weight moisture content can be determined using the following equation:

$$M = \frac{w - d}{w}$$

M = moisture content (%)

w = initial weight of sample (kg)

d = weight of sample after drying at 105°C (kg)

Table 2.3: Typical moisture contents of wastes (Williams, 2007)

Source of solid waste	**Type of Waste**	**Moisture Content, %**	
		Range	**Typical**
Residential	Food wastes (mixed)	50 – 80	70
	Paper	4 – 10	6
	Plastics	1 – 4	2
	Yard Wastes	30 – 80	60
	Glass	1 – 4	2
Commercial	Food wastes	50 – 80	70
	Rubbish(mixed)	10 – 25	15
Construction and demolition	Mixed demolition combustibles	4 – 15	8
	Mixed construction combustibles	4 – 15	8
Industrial	Chemical sludge (wet)	75 – 99	80
	Sawdust	10 – 40	20
	Wood (mixed)	30 – 60	35
Agricultural	Mixed agricultural waste	40 – 80	50
	Manure (wet)	75 – 96	94

2.10.1.3 Particle Size and Distribution

The size and distribution of the components of wastes are important for the recovery of materials, especially when mechanical means are used, such as trommel screens and magnetic separators. Particle size distribution, like the percentage of combustibles, is relevant to incineration and biological transformation methods. Particle size is also relevant for recycling and reuse and for equipment sizing for further treatment (Gerald, 1997). For example, ferrous items which are of a large size may be too heavy to be separated by a magnetic belt or drum system. The size of waste components can be determined using the following equations:

$$Sc = \frac{L + W}{2}$$

Sc = L	Sc: size of component, mm
Sc = (L+w)/2	L: length, mm
Sc = (L+w+h)/3	W: width, mm h: height, mm

2.10.2 Chemical properties

Chemical properties of MSW are very important in evaluating the alternative processing and recovery options. This is especially important where waste are burned for energy recovery, in which case the most important properties are Proximate analysis, fusing point of ash, Ultimate analysis (major elements), Energy content(Techobanaglous *et.al.,* 1993).

2.10.2.1 Proximate Analysis

Proximate analysis for the combustible components of MSW includes the following tests: Moisture (drying at 105 ^{o}C for 1 hr), Volatile combustible matter (ignition at 950 ^{0}C in the absence of oxygen), fixed carbon (combustible residue left after Step 2) and ash (weight of residue after combustion in an open crucible). Fixed carbon is the carbon remaining on surface as charcoal. A waste with high fixed carbon requires a longer detention time on the surface of the furnace to achieve complete combustion than the waste with a low fixed carbon load. Typical proximate analysis values are showed in Table 2.4.

Table 2.4: Typical Proximate Analysis Values (% by weight) (Techobanaglous *et.al.*, 1993)

Type of Waste	Moisture	Volatiles	Carbon	Ash
Mixed food	70.0	21.4	3.6	5.0
Mixed paper	10.2	75.9	8.4	5.4
Mixed plastics	0.2	95.8	2.0	2.0
Yard wastes	60.0	42.3	7.3	0.4
Glass	2.0	-	-	96-99
Residential	21.0	52.0	7.0	20.0

2.10.2.2 Ultimate Analysis

Involves the percentage determination of C (carbon), H (hydrogen), O (oxygen), N (nitrogen), S (sulphur) and ash. The determination of halogens is often included in an ultimate analysis. The results are used to characterize the chemical composition of the organic matter in MSW, to define the proper mix of waste materials to achieve suitable C/N ratios for biological conversion processes, to determine heating value of MSW by modeling and to determine released gases when combustion takes place.

Table 2.5: Typical data on ultimate analysis of combustible materials found in SW (Tchobanoglous *et al*., 1997)

Percent by weight (dry basis)						
Type of waste	Carbon	Hydrogen	Oxygen	Nitrogen	Sulphur	Ash
Food and food products						
Fats	73.0	11.5	14.8	0.4	0.1	0.2
Food waste (mixed)	48.0	6.4	37.6	2.6	0.4	5.0
Fruit wastes	48.5	6.2	39.5	1.4	0.2	4.2
Meat wastes	59.6	9.4	24.7	1.2	0.2	4.9
Paper products						
Cardboard	43.0	5.9	44.8	0.3	0.2	5.0
Magazines	32.9	5.0	38.6	0.1	0.1	23.3
Newsprint	49.1	6.1	43.0	‹ 0.1	0.2	1.5
Paper(mixed)	43.4	5.8	44.3	0.3	0.2	6.0
Waxed cartons	59.2	9.3	30.1	0.1	0.1	1.2
Plastics						
Plastics (mixed)	60.0	7.2	22.8	-	-	10.0
polyethylene	85.2	14.2	-	‹0.1	‹0.1	0.4
Polystyrene	87.1	8.4	4.0	0.2	-	0.3
Polyurethane[b]	63.3	6.3	17.6	6.0	‹0.1	4.3
Polyvinyl chlo.	45.2	5.6	1.6	0.1	0.1	2.0
Textiles, rubber, leather						
Textiles	48.0	6.4	40.0	2.2	0.2	3.2
Rubber	69.7	8.7	-	-	1.6	20.0
Leather	60.0	8.0	11.6	10.0	0.4	10.0
Wood, trees, etc						
Yard wastes	46.0	6.0	38.0	3.4	0.3	6.3

Wood (green timber)	50.1	6.4	42.3	0.1	0.1	1.0
Hardwood	49.6	6.1	43.2	0.1	‹0.1	0.9
Wood(mixed)	49.5	6.0	42.7	0.2	‹0.1	1.5
Yard wastes	46.0	6.0	38.0	3.4	0.3	6.3
Glass, metals, etc.						
Glass and mineralsc	0.5	0.1	0.4	‹0.1	-	98.9
Metals (mixed)c	4.5	0.6	4.3	‹0.1	-	90.5
Miscellaneous						
Office sweepings	24.3	3.0	4.0	0.5	0.2	68.0
Oils, paints	66.9	9.6	5.2	2.0	-	16.3
Refuse-derived fuel (RDF)	44.7	6.2	38.4	0.7	‹0.1	9.9

2.10.2.4 Energy content

The energy content of the components of waste can be determined using a boiler system, laboratory bomb calorimeter, or by calculation using elemental composition (Techobanaglous *et al*., 1993) or by using mathematical models based on Kathiravale (2003). It is important for feasibility study of municipal solid waste for incineration plan based on their energy value.

An evaluation of the potential of the waste material for use as a fuel in the incinerator requires the determination of its heating value, expressed as kilo joules/ kilo grams (kJ/kg). The heating value is determined experimentally using bomb calorimeter test in which the heat is generated at a constant temperature of 25^{o}C from the combustion of dry sample. The heating values are important in the evaluation of incineration process as a means of energy recovery or disposal (Kathiravale, 2003).

2.11 Energy recovery from municipal solid waste

Municipal Solid Waste (MSW) contains organic as well as inorganic matter. The latent energy present in its organic fraction can be recovered for gainful utilization through adoption of suitable Waste Processing and Treatment technologies.

The recovery of energy from wastes also offers a few additional benefits as follows: The total quantity of waste gets reduced by nearly 60% to over 90%, depending upon the waste composition and the adopted technology; Demand for land, which is already scarce in cities, for land filling is reduced; The cost of transportation of waste to far away landfill sites also gets reduced Proportionately; and net reduction in environmental pollution.

It is, therefore, only logical that, while every effort should be made in the first place to minimize generation of waste materials, recycle and reuse them to the extent feasible, the option of Energy Recovery from Wastes be also duly examined. Wherever feasible, this option should be incorporated in the over-all Scheme of Waste Management. Study energy potential of municipal solid waste is important for the recovery of energy. Building of transfer station near the source for energy recovery to separate the waste is based on their classification and energy potential value.

2.11.1 Basic Techniques of Energy Recovery from MSW

Energy can be recovered from the organic fraction of waste (biodegradable as Well as non-biodegradable) basically through two methods as follows: Thermo-chemical conversion: This process entails thermal de-composition of organic matter to produce either heat energy or fuel oil or gas; and Bio-chemical conversion: This process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol (Tchobanoglous *et al* (1996).

The Thermo-chemical conversion processes are useful for wastes containing high percentage of organic non-biodegradable matter and low moisture content. The main technological options under this category include Incineration and Pyrolysis/ Gasification. The bio-chemical conversion processes, on the other hand, are preferred for wastes having high percentage of organic bio-degradable (putrescible) matter and high level of moisture/ water content, which aids microbial activity. The main technological options under this category are Anaerobic Digestion also referred to as Biomethanation (Tchobanoglous *et al* (1977).

2.11.2 Factors affecting Energy Recovery

The main parameters which determine the potential of recovery of energy from Wastes (including MSW), are: Quantity of waste, and Physical and chemical characteristics (quality) of the waste. The actual production of energy will depend upon specific treatment process Employed, the selection of which is also critically dependent upon (apart from certain other factors described below) the above two parameters. Accurate Information on the same, including percentage variations thereof with time (daily/seasonal) is, therefore, of utmost importance.

The physical parameters requiring consideration include: size of constituents, density, and moisture content smaller size of the constituents' aids in faster decomposition of the waste. Wastes of the high density reflect a high proportion of biodegradable organic matter and moisture. Low density wastes, on the other hand, indicate a high proportion of paper, plastics and other combustibles. High moisture content causes biodegradable waste fractions to decompose more rapidly than in dry conditions. It also makes the waste rather unsuitable for thermo-chemical conversion (incineration, pyrolysis/ gasification) for energy recovery as heat must first be supplied to remove moisture (Gerald, 1997).

The important chemical parameters to be considered for determining the energy recovery potential and the suitability of waste treatment through bio chemical or thermo-chemical conversion technologies includes volatile solids, fixed carbon content, inert, calorific value, C/N ratio (Carbon/Nitrogen ratio), Toxicity. The desirable range of important waste parameters for technical viability of energy recovery through different treatment routes is given in the table 2.11 the parameter values indicated therein only denote the desirable requirements for adoption of particular waste treatment method and do not necessarily pertain to wastes generated / collected and delivered at the waste treatment facility. In most cases the waste may need to be suitably segregated/ processed/ mixed with suitable additives at site before actual treatment to make it more compatible with the specific treatment method. This has to be assessed and ensured beforehand (Gerald, 1997).

Table 2.6: Desirable range of important waste parameters for technical Viability of energy recovery

Waste treatment method	Basic principle	Important waste parameters	Desirable range
Thermo-chemical conversion	Decomposition of organic matter by	Moisture content	< 45%
		Organic/volatile	> 40%
Incineration Pyrolysis Gasification	action of heat	mater	
		Fixed carbon	< 15%
		Total Inert	< 35%
		Calorific value (Net calorific value)	> 1200k-cal/kg
Biochemical conversion Anaerobic digestion/ Bio-methanisation	Decomposition of organic matter by microbial action	Moisture content	> 50%
		Organic volatile matter	> 40%
		C/N ratio	25-30

2.11.3 Assessment of Energy Recovery Potential

A rough assessment of the potential of recovery of energy from MSW through different treatment methods can be made from knowledge of its calorific value and organic fraction, as under: In thermo-chemical conversion all of the organic matter, biodegradable as Well as non-biodegradable, contributes to the energy output: Total waste quantity: W tonnes Net Calorific Value: (NCV) k-cal/kg.

Energy recovery potential (kWh) = NCV x W x 1000/860 = 1.16 x NCV x W

Power generation potential (kW) = 1.16 x NCV x W/ 24 = 0.048 x NCV x W

Conversion Efficiency = 25% Net power generation potential (kW) = 0.012 x NCV x W

If NCV = 1200 k-cal/kg., then Net power generation potential (kW) = 14.4 x W (Techobanaglous *et al.*, 1993).

2.12 Wastes as Fuel and criteria for incineration

A most crucial factor in the feasibility of an MSW incineration plant is the nature of the waste and its calorific value. If the mandatory criteria for waste combustibility are not fulfilled, the project should be terminated. As a result of the socio-economic situation in many low to middle income countries or areas, only limited amounts of useful resources are wasted. Organized recycling activities in the waste handling system tend to reduce the amount of paper, cardboard, and certain types of plastic in the waste. Additionally, the waste may have high ash and moisture content. Municipal solid waste in such areas therefore often ends up with a low calorific value and its ability to burn without auxiliary fuel is questionable either year round or in certain seasons (Techobanaglous *et al*., 1993).

In areas with heavy precipitation, closed containers for collection and transportation should be used to avoid a significant increase of the water content of the waste. Industrial, commercial, and institutional wastes (except from market waste) tend to have a significantly higher calorific value than domestic waste. Mixing different types of wastes may therefore make incineration possible. However, the collection system must be managed well to maintain segregated collection under these circumstances (Techobanaglous *et al*., 1993).

2.12.1 Key Criteria for Waste as Fuel

A preliminary feasibility assessment of using a particular waste as fuel can be made on the basis of the content of ash, combustible matter (ignition loss of dry sample), and moisture. The average annual lower calorific value must be at least 7 MJ/kg, and must never fall below 6 MJ/kg in any season; Forecasts of waste generation and composition are established on the basis of waste surveys in the catchment area of the planned incineration plant; Assumptions regarding the delivery of combustible industrial and commercial waste to an incineration plant should be founded on an assessment of positive and negative incentives for the various stakeholders to dispose of their waste at the incineration facility; The annual amount of waste for incineration should not be less than 50,000 tons, and the weekly variations in the waste supply to the waste incineration plant should not exceed 20 percent. Moisture contents (MC) greater than 50% are generally not suitable for combustion since the energy required to evaporate the water reduces the efficiency. Typically the combustion process will produce about 25% bottom ash by weight of the input. The maximum amount of energy recoverable through MSW incineration depends primarily on the lower calorific value of the waste, but also on the system applied for energy recovery. It is most efficient when both electricity and steam/heat are produced, and the yield is lowest when only electricity is generated and the surplus heat is cooled away. Energy prices vary greatly from place to place, even within the same country. Electricity is a high-value energy form, so a low energy yield is, to some extent, compensated for through price differences (Techobanaglous *et al.*, 1993).

2.13 Emissions from municipal Solid waste incineration

The incineration of municipal waste involves the generation of climate-relevant emissions. These are mainly emissions of CO_2 (carbon dioxide) as well as N_2O (nitrous oxide), NOx (oxides of nitrogen) NH_3 (ammonia) and organic C, measured as total carbon. CH_4 (methane) is not generated in waste incineration during normal operation.

The emissions from incineration are not only highly depend on the composition of the incoming waste, but also on the combustion efficiency of the incinerator and the technology used for flue gas treatment Depending on the fuel composition and operational circumstances nitrogen oxides, sulphur dioxide, carbon monoxide, hydrogen chloride, dioxins and furans, hydrogen fluoride, volatile organic carbon and heavy metals are emitted (Williams, 2005).

For the reference waste, the amounts of energy and GHG emissions from landfill or thermal conversion into energy were estimated using various factors reported in the literature. When landfilled, the biodegradable portion of the waste releases CH_4 and carbon dioxide (CO_2). Part of the LFG is recovered, but the remainder diffuses into the atmosphere. Because of its high global warming potential (GWP), CH_4 can significantly contribute to GHG emissions. When waste is burned for energy by incineration or other thermal conversion, fossil carbon in the waste is released as CO_2 together with a small amount of other GHGs such as nitrous oxide (N_2O) and CH_4. However, energy production indirectly reduces GHG emissions by displacing the use of fossil fuels. The amount of displaced fossil fuel depends on the LHV of the waste and the fuel efficiencies for heat and electricity. The emission factors established for landfilling and combustion are then applied to various cases of waste management and fuel efficiencies to identify the potential for energy and reduction of GHG emissions.

Incinerator is a container for burning refuse, or plant designed for large-scale refuse combustion. Thus, incineration is one of the best known methods of managing municipal solid waste disposal. Nevertheless, the environmental consideration must be done before setting up a recuperative energy incinerator.

CHAPTER 3

MATERIALS AND METHODS

3.1 Description of the study Area-Agaro

Agaro town is located in Western Oromia Regional State and included in jimma zone, it is 390km far from Addis Ababa and 45km from Jimma . At latitude of $36^{0}35^{'}$E and longitude of $7^{0}35^{'}$N. The elevation ranges from 800mm to 1600mm above sea level. The area receives an annual rainfall of 1500mm to 2000mm. Agaro Town is about 2146 hectare. The main economic activities in the town are commerce (trading and catering services) and small scale manufacturing enterprises. The industries in the town are small- scale and cottage industries like grain mills, oil mills, wood & metal workshops, coffee hullers, hollow block manufacturing, bakeries and pastries, and multipurpose shops. The dominant manufacturing activities that account 70% of the total number of manufacturing enterprises in the town are grain mills, wood works and coffee hullers. The size of population is listed under Table 3.1.

Table 3.1: Demographic data (Agaro Town municipality, 2010)

Categories	**Population size**
Male	46033
Female	43159
Total	89,192

3.2 Methodology

The methodology followed for this study involves review of related literatures; collection of sample from dumpsite, sorting and measurement of municipal solid waste in the dumpsite for composition determination; proximate analysis which is done at Jimma college of agriculture department of post-harvest management; ultimate analysis done based on the typical ultimate analysis that derived from different sources.

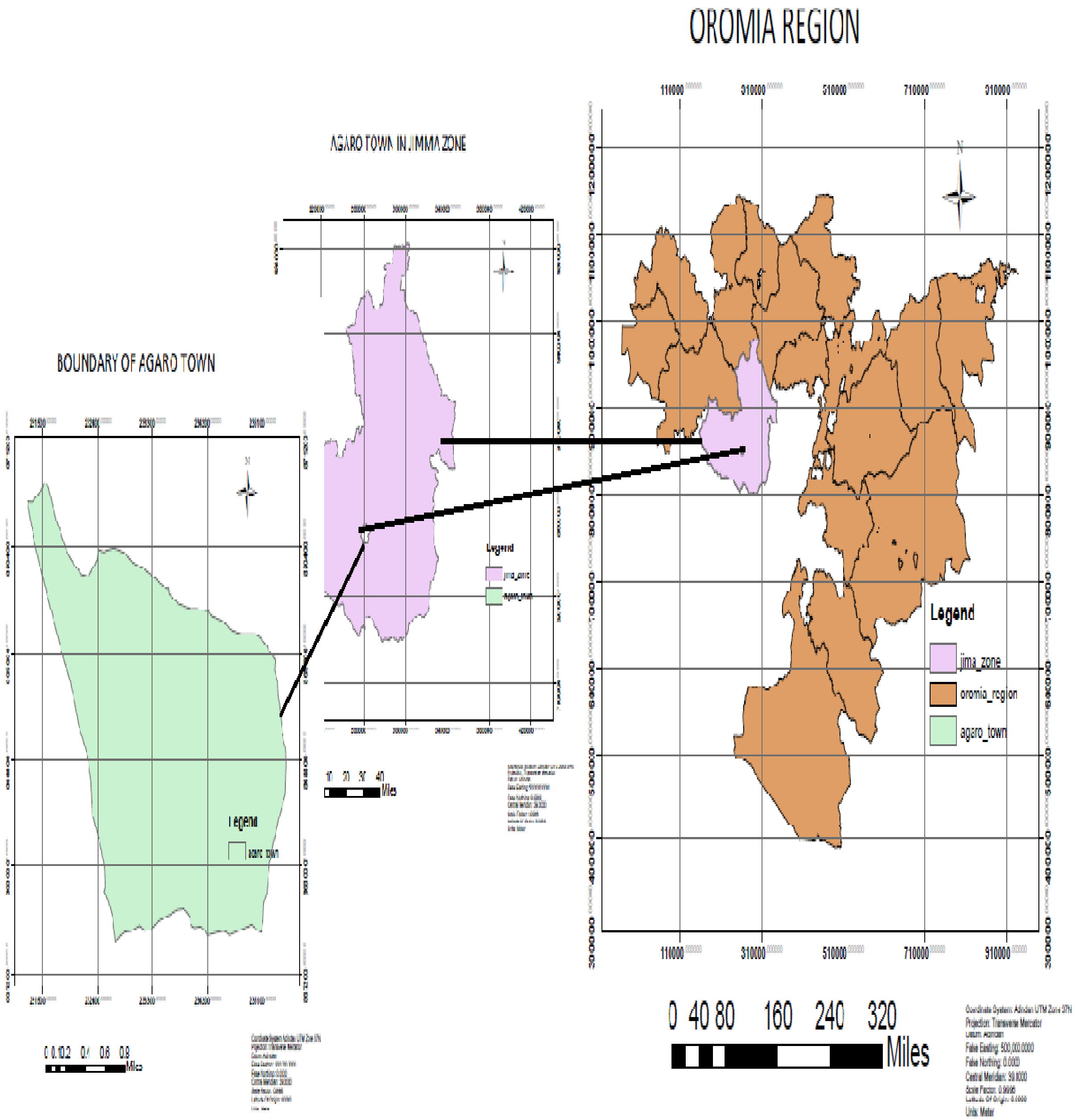

Figure 3.1 Map of study area

3.2.1 Method of Sampling

Agaro is small Town with insufficient waste management, waste collection done by two organizations these are Agaro Town municipality and Agaro Town micro small industry office.

In Agaro Town waste collected in each house for a week then the waste that collected in front of each house is then collected by Agaro Town municipality and micro small industry once a week. The collected waste then dumped to Koye dump site which is located 10km from the Town. For this study about 100kg sample was taken purposively from dump site, just when they dump waste to the site (fresh waste) the track collect waste from five kebeles (since Agaro Town has five Kebeles the track had made five trip) so waste sample was collected from each trip (20kg) after this the waste separate in its component and measured. The collected waste for laboratory work is about 25g from each component.

Figure 3.2: Municipal solid waste of Agaro Town

3.2.2 Sorting of Solid Waste

Sorting is a process by which a component MSW separated from mass waste. Manual sorting was performed by five sorters for four hour; all sorting personnel worked in the dumpsite for a lot of years; they had a know how to identifying the type of waste and technical requirements of the sorting process. The collected solid waste sample after sorting process would divide to 9 categories, this waste then measured for their weight, volume and density, next the waste separated according to the selected classification such as chat, paper, plastic, food, textile, glass, metal and yard waste, cardboard each category was weighted for percentage distribution of each waste component. For laboratory work it have been taken seven types of waste component by excluding metal and glass. Based on literature information these waste types are not suitable for recovery of energy by combustion because they needs excess heating and release high emission gases when they are combusted.

3.2.3 Data collection

The waste are collected from dump site when track dumped waste to the site based on the trip of track means from each trip 20 kg waste collected since the track had five trip then 100 kg waste collected that's the amount needed for our sample. Then after the waste collection, sorting of waste into different components was made .The sorted components then weighted and their volume was determined using different sized wood boxes with a known volume. Finally the size distribution of the waste was determined using a 50 mm and 10 mm sized mesh wires and then the weight and volume measurements done for both size ranges.

3.2.4 Proximate analysis

Proximate analysis consist of moisture content, ash content, volatile matter and fixed carbon determined by putting the selected sample to different range of the temperature, between 105 °C to 925 °C. In order to reduce the magnitude of error arising from the moisture change and from decomposition the analysis of the sample was started within two to three hours after collection. Care was also taken to make the samples are well mixed and each waste component were taken and chopped manually to reduce the size. The well mixed sample finally taken for laboratory analysis.

Figure 3.3: Sample measuring for proximate analysis

a) Determination of moisture contents

In the wet-weight method of measurement, the MC in a sample was expressed as a percentage of the weight of the material when wet whereas in the dry-weight method, it was expressed as a percentage of the weight of the material when dry. The study used the dry-weight method. The moisture content was determined according to ASTM E871-82 standard. An empty container was preheated for twenty minutes and then fifty grams of waste sample was quickly put into the container. The sample was placed in an oven at a temperature of 105°C for one hour and then cooled to room temperature and reweighed. The difference in weight represents the moisture content of the sample expressed in percentage. These MC in the samples were calculated using equation 3.1

$$M = \frac{S-B}{S} * 100 \quad (3.1)$$

Where M = moisture content in percentage (%),

S = weight of sampled waste

B = weight of sampled waste after heating

B) Volatile matter

Volatile matter calculation was determined using equation 3.2.

$$V = \frac{A-B}{A} * 100 - M \quad (3.2)$$

Where V = volatile matter in percentage

A = weight of sampled wastes before heating in grams

B = weight of waste after heating in grams

M = moisture contents determined from equation 3.1

C) Ash content

Ash content of solid waste is the non-combustible residue left after waste is burnt. The ash content was determined using E1534-93 standard. Three grams of sampled waste was placed into a weighed and uncovered crucible, then placed into the muffle furnace. The power was switched on and the temperature maintained at 925°C for 7 minutes. The crucible and its content was removed from the furnace and weight recorded after it is cooled. Ash content was determined using equation 3.3.

$$As = \frac{A-B}{C} * 100 \quad (3.3)$$

Where As = ash content percentage

A = weight of container and ash residue grams

B = weight of empty container grams

C = weight of sampled waste used (with moisture content)

D) Fixed carbon

The fixed carbon of a fuel is the percentage of carbon available for char combustion. Fixed carbon gives an indication of the proportion of char that remains after the devitalization phase. The fixed carbon was calculated by subtracting the sum of moisture, ash and volatile matter from 100 percent. It contains the errors and scatters of the other three measurements and is regarded as an approximate figure. Fixed carbon content was calculated using equation 3.4

$Fc = 100 - (M+V+A_S)$ -- (3.4)

Where

FC = fixed carbon %

M = total moisture %

V = volatile matter %

As = ash content %

F) Density is equal to mass waste over volume of waste.

$$\boldsymbol{\rho = \frac{M}{V}}$$

Where ρ = Density of waste as it discarded

M = mass waste

V= volume of waste (which is measured by box that have 20*20*10 dimension)

3.2.5 Elemental (ultimate) analysis

The carbon (C), hydrogen (H), oxygen (O), sulphur(S) and nitrogen (N) determination in biomass represents the so called elemental analysis. These elements are detected by flash EA1112 thermo flash gas analyser except oxygen. Oxygen is determined by difference based on other element determination. About 10 mg of sample are burned at 900°C in an oxygen atmosphere, so the C is converted into CO_2, H in H_2O, S into SO_2 and the N in N_2. The first three compounds are detected quantitatively by an IR detector, while N_2 is determined by a thermal conductivity detector.

3.2.6 Calorific Value

It’s done by Dulong formula

Dulong invented this formula for energy content analysis when the analysis uses some standard element value without using bomb calorimeter.

Energy content (E), KJ/Kg= 337C% + 1428 (H% –O%/8) +9S%

CHAPTER 4

RESULTS AND DISCUSSION

Agaro Town is one of the oldest, populous and fast growing towns of Ethiopia. It is also known by being trade and coffee plantation center. Unlike these features of the Town, municipal solid waste management service provision for its residents is a new phenomenon. The rate of generation of solid waste in the town is very fast since then and it reaches $7750m^3$ per year (Agaro town municipality). As a result of much amount of solid waste, the residents considered MSWM as necessary and vital urban service. The per capital solid waste generation in the town is 0.58 Kg/day/person. Solid waste energy content and proximate and ultimate analysis were done under this study.

4.1 solid waste components

Based on the sample collected from Agaro Town municipality dump site, the nine component of waste include chat, plastic, cardboard, metal, paper, food waste, glass, textile and yard waste, from this waste only 7 waste types were selected based on their energy production capacity and consume less heat during combustion (incineration) this waste include chat, plastic, cardboard, paper, food waste, textile, and yard waste so this wastes are listed with their weight under Table 4.1 and 4.2 respectively.

Table 4.1: the major components of municipal solid waste of Agaro Town

S.NO.	Waste component	Weight (kg)	percent by mass (kg)
1	Chat	34.12	34.12
2	Plastic	16.3	16.3
3	Cardboard	10.5	10.5
4	Metal	9.13	9.13
5	Paper	8.31	8.31
6	Food waste	7.1	7.1
7	Glass	5.3	5.3
8	Textile	5.14	5.14
9	Yard waste	4.1	4.1
	Total	100	100

Metal and glass removed from our sample because literature information tells that these waste types are not suitable for recovery of energy by combustion because they needs excess heating and release high emission gases when they are combusted. So the data without metal and glass is listed below.

Table 4.2 the selected components of municipal solid waste of Agaro Town

S.NO.	Waste component	Weight by mass (kg)	Percent by mass (kg)
1	Chat	34.12	39.87
2	Plastic	16.3	19.05
3	Cardboard	10.5	12.27
4	Paper	8.31	9.71
5	Food waste	7.1	8.29
6	Textile	5.14	6.01`
7	Yard waste	4.1	4.8
	Total	85.57	100

4.2 data collection

data collection is the collected data from office, field and laboratory based on that measure pcg.

PCG = [(waste generation/weeks)(weeks/days)/population]

PCG = [(18650607/4)* (4/360)]

89192

= 0.58 Kg/day.person(per capita waste production of Agaro town)

Table 4.3 components of municipal solid waste with its volume and density.

S.NO.	Component	Percent by mass (kg)	Moisture Content %	Dry mass kg	Density of waste (kg/m^3)	Volume (m^3)
1	Chat	39.87	36.33	21.72	26.4	1.54
2	Plastic	19.05	1	16.14	12.7	1.5
3	Cardboard	12.27	8	9.66	18.59	0.66
4	Paper	9.71	5.33	7.87	16.46	0.59
5	Food waste	8.29	14	6.11	43.63	0.19
6	Textile	6.01`	8.67	4.69	33.38	0.18
7	Yard waste	4.8	20	3.28	21.81	0.22
	Total	100	36.33	69.47	172.97	4.86

4.3 Proximate analyses

Proximate analysis for the combustible components of MSW includes the following tests: Moisture (drying at 105^{o}C for 1 h), Volatile combustible matter (ignition at 950^{o}C in the absence of oxygen), fixed carbon (combustible residue left after Step 2) and ash (weight of residue after combustion in an open crucible). Fixed carbon is the carbon remaining on surface as charcoal. A waste with high fixed carbon requires a longer detention time on the surface of the furnace to achieve complete combustion than the waste with a low fixed carbon load. Based on laboratory result, the proximate analysis values for the west are showed in Table 4.4.

Table 4.4 Proximate Analysis result (% by weight)

S.NO.	Types of Waste	Moisture Content (%)	Volatiles matter (%)	Fixed Carbon (%)	Ash Content (%)
1	Chat	36.33	56.67	0	7
2	Plastic	1	98	0	1
3	Cardboard	8	88.33	0	3.67
4	Paper	5.33	93	0	1.67
5	Food waste	14	76	9	1
6	Textile	8.67	80.33	0	11
7	Yard waste	20	74.67	0	5.33
	Total	93.33	567	0	30.67

A) Moisture content

The moisture content is a measure of the amount of water lost from materials upon drying to a constant weight. It is directly affected by physical and chemical properties of material which enable it to absorb the exiting water in the environment. Table 4.4.1 shows the moisture content analysis of each individual waste component in koye dump site. Based on laboratory analysis result, chat waste with 36.33 percent, yard waste with 20 percent and food waste with 14percent have the highest moisture content in this dumpsite.

Wastes with different moisture contents have different drying characteristics. Those with higher moisture content require a longer drying time and much more heat energy, causing a lower temperature in the furnace; and vice versa. If the moisture content is too high, the furnace temperature will be too low for combustion, such that auxiliary fuel is needed to raise the furnace temperature and to ensure normal combustion.

B) Volatile matter

Volatile matter is that a portion of the wastes which is converted into the gas phases during the heating process (950°C). Organic and combustible materials such as plastic, wood and paper are the components with high percentage of volatile matter usually between 85 to 97 percent. From the waste type plastic waste and paper waste have higher volatile matter with 98 and 93 percent respectively. The useful range of volatile matter for technical Viability of energy recovery is greater than 40%. Since all the waste above this range, from this concludes that the selected municipal solid waste in Koye dumpsite have high organic matter. So it has the capacity to generate more flue gases for heating.

C) Fixed carbon

Fixed carbon is the carbon remaining on surface as charcoal. From the waste type food waste have some fixed carbon load. The percentage of the fixed carbon in waste materials such as food waste (9%) shows that this element requires a longer detention time on the surface of the furnace to achieve complete combustion compared to other waste. The desirable range of fixed carbon for technical viability of energy recovery is less than 15%. Since all waste have below this range, so the waste in the sample is feasible for energy recovery from municipal solid waste by incineration

D) Ash content

The ash content is the remaining ash after volatile matter and fixed carbon are removed. Table 4.4.1 shows that the high percentage of ash content in textile, chat and yard waste with 11%, 7% and 5.33% respectively, dominating in the ash content percentage. The higher percentage of ash content was referred to quantity of textile waste, chat and yard waste. Generally the ash content in the MSW in koye dumpsite is small in ash content which indicates that it has high flue gases.

4.4 Ultimate Analysis

Total element analysis of MSW is conducted to characterize the chemical composition of organic fraction of MSW. Such determination is essential for assessing suitability of the MSW as a fuel and predicting emissions from combustion. The ultimate analysis from different sources presented in Table 4.5

Table 4.5: The typical ultimate analysis from different sources

	Percent by weight (dry basis)					
Types of west	**Carbon**	**Hydrogen**	**Oxygen**	**Nitrogen**	**Sulphur**	**Ash**
Chat	43.91	7.09	39.31	1.29	0.4	8
Plastic	60.0	7.2	22.8	-	-	10.0
Cardboard	43.0	5.9	44.8	0.3	0.2	5.0
Paper	43.4	5.8	44.3	0.3	0.2	6.0
Food waste	48.0	6.4	37.6	2.6	0.4	5.0
Textile	48.0	6.4	40.0	2.2	0.2	3.2
Yard waste	46.0	6.0	38.0	3.4	0.3	6.3

4.4.1 Determination of chemical composition of the solid waste sample

The organic portion of municipal solid waste of Agaro Town means the composition of carbon (C), hydrogen (H), oxygen (O), sulphur (S) and nitrogen (N) determination in biomass represents the so called elementary analysis. This is listed under the table 4.6

Table 4.6 Computation table for the determination of composition of organic portion of municipal solid waste of Agaro Town

Component	Wet mass (kg)	Dry mass (kg)	Composition					
			C	H	O	N	S	Ash
Chat	34.12	21.72	9.54	1.54	8.54	0.28	0.08	1.74
Plastic	16.3	16.14	9.68	1.16	3.68	-	-	1.62
Cardboard	10.5	9.66	4.15	0.57	4.33	0.03	0.02	0.48
Paper	8.31	7.87	3.42	0.46	3.48	0.02	0.02	0.47
Food waste	7.1	6.11	2.93	0.39	2.29	0.16	0.02	0.32
Textile	5.14	4.69	2.25	0.30	1.88	0.10	0.01	0.15
Yard waste	4.1	3.28	1.51	1.2	1.25	0.11	0.01	0.21
Total	85.57	69.47	33.48	5.23	25.45	0.7	0.16	4.99

- The mass of moisture in the organic portion of solid waste sample is:

  Wet mass – Dry mass

  85.57 – 69.47 = 16.1kg

- Converting moisture content reported in table 4.6 to hydrogen and oxygen:
- Hydrogen = 2/18 * 16.1kg =1.79kg
- Oxygen = 16/18 * 16.1 = 14.3kg
- Total mass hydrogen = 1.78 + 5.23 = 7.01 kg
- Total mass of 0xygen = 14.3+ 25.45 = 39.75 kg

Table 4.7: Determination of approximate value for chemical formula with and without sulphur.

Element	Mass (kg)	Molecular mass	Amount (mole)	Normalized Mole ratio Sulphur =1	Normalized Mole ratio Nitrogen=1
Carbon (C) Hydrogen (H) Oxygen (O) Nitrogen (N) Sulphur (S)	33.48 7.01 39.75 0.7 0.16	12.01 1.01 16.00 14.01 32.06	2.7877 6.9406 2.4844 0.0499 0.0049	568.918 1416.449 507.020 10.184 1	55.866 139.098 49.787 1.0 -

- Hence, the chemical formula of the solid waste sample with sulphur is:

$$C_{568.918}H_{1416.449}O_{507.020}N_{10.184}S$$

- And its chemical formula without sulphur is:

$$C_{55.866}H_{139.098}O_{49.787}N$$

4.5 Calorific value for municipal solid waste sample

As a mixture of various kinds of waste, MSW has very complex ingredients. Heating value of MSW, as an indicator of combustible contents in MSW, plays a key role in determining the measure of MSW handling. If MSW can be handled with incineration and pyrolysis, heating value serves as an important parameter in deciding for incineration plan (Zhang, 1997).

Removing particular materials from MSW prior to incineration (e.g., through source separation) can affect combustibility. For example, removing other wastes and inorganic recyclable such as glass and metals can reduce moisture and increase average HHV. In contrast, removing paper and plastics lowers HHV and increases moisture content. The net effect will depend on exactly what is removed. The content done by Dulong formula

Energy content (E), KJ/Kg= 337C% + 1428 (H% –O%/8) +9S%----------------------------- (4)

4.5.1 Estimation of energy content approximation of the solid waste sample

Using equation 4 and data obtained in Table 4.8 below, to obtain the energy content of the solid waste generated in Agaro Town.

Table 4.8: Percentage by mass composition of elements and ash

Component	**Mass (kg)**	**Percentage by mass (%)**
Carbon	33.48	38.89
Hydrogen	7.01	8.14
Oxygen	39.75	46.17
Nitrogen	0.7	0.82
Sulphur	0.16	0.19
Ash	4.99	5.79
Total	86.09	100

The energy content done by Dulong formula as follow

Energy content (E), KJ/Kg = 337C% + 1428 (H% –O%/8) +9S%

E = 337 (38.89) + 1428(8.14-46.17/8) + 9(0.19) = **16490.22KJ/Kg**

= 13105.93 + 3382.575 + 1.71 = **16490.22KJ/kg**

= 16.49MJ/kg

It is important to know the amount of energy the MSW mixed waste samples contain as means of understanding the potential of the waste feed stock as a source of fuel. From the above result it can be harvested 16490.22KJ per kg of municipal solid waste of Agaro Town. Therefore, higher the calorific value of the waste and lower moisture content, the more energy can be extracted. According GIZ and PCD (2003), if the solid waste has a calorific value of 11-17 MJ/kg or more, it is highly recommended for use as refuse-derived fuel (RDF). The results showed that the MSW of Agaro Town had high calorific value. This showed that the MSW might be of great value in thermal process in order to obtain high energy.

Studies conducted in Changzhou and Guangzhou in China show raw MSW of low calorific value reporting at 3 to 4 MJ/kg while in Kuala Lumpur, Malaysia and Parona, Italy report values ranging 10 - 16.8 MJ/kg and 10.5 – 16.17 MJ/kg respectively (*Mater*, 2008). When compared with those city Agaro Town municipal solid waste with 16.5 MJ/kg better in energy recovery so it’s good to use as source of energy.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

With the development of national economy, the accelerating urbanization and the continued improvement of living standard, the output of the solid waste, particularly Municipal solid waste is constantly increasing. This causes environmental pollution and potentially affects people's health, preventing the sustained development of cities and drawing public concern in all of the society. The continuously generated wastes take up limited land resources, pollute water and air, and consequently lead to serious environmental trouble. Proper waste treatment is therefore an urgent and important task for the continued development of cities in this work, calculation of calorific value of municipal waste has been carried out from the elemental composition of the waste using Dulong's formula. The result of 16490.22KJ/kg obtained agrees with type 1 waste, (Engineering, 2009) that contains 25 percent moisture contents from waste classifications. With this heating value, maximum temperature of the flue gas of 833.7K was calculated from the heat balance equation in the furnace.

In our work that fixed carbon of the waste is very low this shows most of the waste have short detention time this behavior of the waste important in the recovering energy from Municipal solid waste. On the other hand the waste which had high volatile matter this indicates the capacity of municipal solid waste to generate more flue gases for heating. The recovery of energy from wastes also offers other benefits as follows

- The total quantity of waste gets reduced by nearly 60% to over 90% depending upon the waste composition and the adopted technology.
- Demand for land, which is already scarce in cities for land filling is reduced,
- The cost of transportation of waste to far-away landfill sites also gets reduced proportionately and net reduction in environmental pollution.

It is highly recognized that the existing solid waste collection and disposal services are Inadequate both in terms of coverage and sanitary treatment of the waste. The solid waste collection service coverage is very low which means the major portion of the solid waste generated within the city is uncontrolled and improperly disposed which creates unhealthy environment to live and work in. No condition is available for community and private sector involvement in re-use, recycle and composting of the waste. But it can create job opportunity for the unemployed citizens of the town. In general waste management is not considered as important development sector to meet the goals set in the national and regional policies and strategies for sustainable development. There were no awareness raising education and provision to proper training of residents with regard to residential solid waste management methods in the town. This has aggravated the waste management problems and challenges thus leading to public health, aesthetic and ecological concerns. Municipal solid waste (MSW) is a domestic energy resource with the potential to provide a significant amount of energy. The amount of this energy identified as an important issues affecting the suitability of design the waste to energy plan. The higher average heating value (about16490.22 kJ/kg) of collected MSW showed the potential for incineration and energy recovery.

This study provides an overall picture and impacts, and hence, can support a decision-making process for implementation of MSW incineration. The results obtained in this study could provide valuable information to implement incineration. But it should be noted that the results show the characteristics only from some viewpoints.

5.2 Recommendations

- Agaro Town which is known for its poor municipal solid waste management, so this must improved for the future for efficient collection of waste.
- The waste collected in front of each house, this practice is not good for health since the waste stay there for a week this can result for health deterioration so the container must be arranged by municipality to reduce the problem.
- The municipality has to increase public awareness. Wastes disposed of illegally at any open spaces are not only because of lack of nearby containers or lack of

municipal waste collection services but also due to lack of awareness and a consequence of mismanaged municipal wastes.

- The expert that works in the municipality on waste management has not qualified for that job so this must be considered by the authority.
- Thus based on the generation rate and composition of solid wastes in Agaro town, integrated solid waste management system which combines a range of solid waste treatment options like source reduction, composting, recycling and waste to energy transformation is recommended.
- The municipality faced lack of tracks which take the waste from each house to dump site they still work with two tracks which is not fit with the waste produced in the Town.
- Government and different stakeholder as well as private organizations should invest on utilization of koye municipal solid waste for energy use by incineration and then improve the people attention for solid waste. For example, implement small scale incineration plant for heating and electricity (For industries and condominium) or small scale incineration that only use as heating purpose. It is the least expensive plant equipped with hot water boiler only.
- The existing Agaro Town municipal solid waste which is disposed of at koye dumpsite is the potential for energy recovery by combustion since it had high compostable component.

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Plate 1 Agaro Town municipal solid waste at Koye dump site



Plate 2 Agaro Town municipal solid waste at Koye dump site

Plate 3 the box used for volume determination

Plate 4: the final sorted sample waste in plastic bag after collected from koye dump site

Plate 5: types of sample waste in the laboratory

Plate 6: sample that ready for laboratory

Plate 7: measuring sample waste weight for proximate analysis